

CENTRAL INTELLIGENCE AGENCY

INFORMATION REPORT

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COUNTRY : USSR (Leningrad Oblast)

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SUBJECT : Comparison of Ballistic Data on the Wasserfall NO. OF PAGES 15
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INTRODUCTION

1. The data [] submitted in the following report are based on the antiaircraft rocket Wasserfall, in the form in which it was developed in 1946-1948 at Branch No. 1, Gorodnitsa Island, and on the project R-113, which was developed in the same place during 1950-1951. The numerical values are partly [] and partly from a series of trajectory computations. The trajectory computations are approximate and contain several inaccuracies because the thrust is only represented by an average value; the increase in thrust when the air pressure decreases with the altitude is not taken into consideration in an accurate form and the air resistance cannot be computed exactly because of a lack of information on the resistance coefficients. However, the results do agree in magnitude with those which resulted from the investigations at Gorodnitsa Island.

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LIST OF TABLES AND FIGURES

2. [] listed below the various tables and diagrams []
These tables and diagrams /pages 6 to 15/ make possible a comparison of the data of the Wasserfall and R-113. There is more

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EXPLANATIONSDimensions (Table 1, Item 1) [page 6]

3. The length of the R-113 was from 1 to 1.5 meters longer than the Wasserfall. The missiles did not differ essentially in width or diameter. The Wasserfall was designed with four wings while the R-113 was designed with two wings.

Weights (Table 1, Items 2) [page 6]

4. The starting weights of the Wasserfall and the R-113 were approximately the same. Some savings were made in the structural weight of the R-113 as compared with the Wasserfall so that the weight ratio at the termination of combustion was .39 compared to .455 for the Wasserfall. The R-113 could carry more fuel because of approximately ten per cent greater length.

Useful Load (Table 1, Item 3) [page 6]

5. The useful load of the R-113 was 500 kg. In the computations for the Wasserfall, this load was possibly smaller than 500 kg.

Thrust (Table 1, Item 4) [page 6]

6. In the Wasserfall, the thrust on the ground was about eight tons. After deducting the loss because of the controls which are carried along for the first 17 seconds after the start, the thrust was perhaps somewhat less. The value of eight tons can be taken as an average value for the whole trajectory.
7. The R-113 was supposed to be started with more thrust so that it would not have to fly too long. The first design provided for a specific thrust acceleration at the start of $\phi = 2.5$; this meant a thrust of 9.5 tons on the ground. It is possible that the final project had a smaller ϕ which was perhaps under 2.3. Thus, the thrust at the start was to be about 8.6 tons. The greater thrust of the R-113 compared to the Wasserfall is due to the fact that the fuel consumption rate and exhaust velocity are both greater.
8. At the start of the work on project R-113, it was intended to avoid the high pressure sphere which was used in the Wasserfall.

[redacted] a sphere with nitrogen was still used in the final R-113 design. But the pressure was not adequate to make it possible for the missile to fly the whole trajectory with complete thrust. The thrust decreased to almost three tons at the termination of combustion. The decrease in thrust was quite desirable on the one hand because in this way a too quick increase of speed was avoided and the impact pressure did not become too high. For a time, it was even planned to regulate the thrust with the help of an air-speed indicator so that the impact pressure remained constant at 10 tons/m².

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detailed explanation of the individual items in the section below.

Table 1 Comparative data of the Wasserfall and the R-113
[page 6].

Table 2 Values for the powered trajectory of the Wasserfall
[page 7].

Table 3 Trajectory values of the R-113 if it could be flown
without a decrease in thrust [page 8].

Table 4 Maximum permissible speed, dependent on the altitude,
if the impact pressure is not to exceed 10 ton/m^2
[page 9].

Figure 1 Time curve of the speed v , the altitude h and the
impact pressure q for the vertical ascent of the
Wasserfall [page 10].

Figure 2 Time curve of the speed v , the altitude h , the impact
and the path angle θ for a sloping powered trajectory
of the Wasserfall [page 11].

Figure 3 Time curve of the speed v , the altitude h and the
impact pressure q for the vertical ascent of the
R-113 [page 12].

Figure 4 Time curve of the speed v , the altitude h , the impact
pressure q and the path angle θ for a sloping powered
trajectory of the R-113 [page 13].

Figure 5 Speed v as dependent on the altitude h for the
sloping trajectories of the Wasserfall (—),
the R-113 (---), and for the case that the impact
pressure q is constantly equal to 10 ton/m^2
(----) [page 14].

Figure 6 Impact pressure q as dependent on the altitude h
for the sloping trajectories of the Wasserfall
(—), the R-113 (---), and for $q = 10$
 ton/m^2 (----) [page 15].

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How much of this plan was still left in the final project is not known to me. It is quite possible that in the end the natural decrease in thrust as a result of the abatement of the pressure in the sphere was considered satisfactory.

9. The combustion period of the Wasserfall was 46 seconds and would have been the same in the R-113 if the complete thrust could have been used on the whole powered trajectory. Because of the decrease in thrust with the lower flow quantity, the fuel lasted about 50 per cent longer, i.e., the combustion period was about 70 seconds.

Wasserfall Trajectories (Table 1, Items 5 and 6; Table 2; Figures 1 and 2 /pages 6, 7, 10 and 11/.

10. From the Wasserfall, the computations with vertical and sloping trajectories resulted in almost the same cut-off velocity of about 800 m/sec. because of the greater air resistance in the sloping trajectories; consequently, the gain in speed because of the more favorable gravitation components is lost again. In Table 2, Figure 1 and Figure 2, the same speed variation is assumed for the vertical ascent and for the trajectory with turning program up to the path angle $\gamma = 30^\circ$. For the middle part of the trajectories, this does not quite agree with reality but it is not an important error. In the sloping trajectory, a schematic variation was assumed as a program for the path angle, and this is shown in Figure 2. The trajectories which are analyzed are powered trajectories. Of course, the combat zone extends some distance beyond the combustion cut-off point.

R-113 Trajectories (Table 1, Items 5 and 6; Table 3; Figures 3 and 4 /pages 6, 8, 12 and 13/.

11. The values in Table 3 and in the Figures 3 and 4 are based on trajectories for which the thrust remains constant during the whole combustion period, i.e., for which the decrease in thrust which actually takes place after a time is not taken into consideration. At full thrust the combustion cut-off comes after about 45 seconds flying time at 20 km. altitude for the vertical ascent. Because of the decrease in thrust, the actual powered trajectory is longer, but the altitude of 30 km. is still reached on the propulsion branch. At this height the speed is somewhat lower than the terminal value in Figure 3. The curve actually runs lower than the one in Figure 3 and is without the kink. The combustion cut-off velocity has a value of about 1000 m/sec. and is shown in Table 1.
12. At full thrust the sloping trajectory has a combustion cut-off speed of 1260 m/sec. at a height of 12 km. The decrease in thrust lengthens the powered trajectory to over 20 km. altitude and the cut-off velocity is still at least 1100 m/sec. The last distance up to the corner of the required combat zone at 30 km. altitude must be covered in free flight. The curve for decreased thrust is below that given in Figure 4 and ends lower down than the one shown on the figure.

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Impact Pressure in R-113 Trajectories (Table 4; Figures 4, 5 and 6)
/pages 9 , 13 , 14 and 15/

13. One result of the lower speed governed by the decrease in thrust is that the maximum of the impact pressure is lowered as compared with the values given in Table 3 and Figure 4. In fact, the maximum value of 10 tons/m^2 provided for the impact pressure in the first design is exceeded, but the maximum pressure in sloping trajectories with decreased thrust is much less than in the case of full thrust and is approximately the same size as for the Wasserfall. In steep trajectories it is about $8-10 \text{ tons/m}^2$ and in sloping trajectories about $17-20 \text{ tons/m}^2$. (Calculations for these lower pressures were not given.)
14. The curve of the speed, if the impact pressure were to be held constantly to 10 tons/m^2 and the speed and impact pressure curves as they really are, recorded against the altitude, for the sloping trajectories of Wasserfall and of R-113 in the case of full thrust, can be seen from Table 4 and Figures 5 and 6. For the trajectory of R-113 with decrease in thrust, the curve for the impact pressure runs between the solid curve (Wasserfall) and the dotted curve (R-113 without decrease in thrust) in Figure 6 and has its maximum at approximately 20 tons/m^2 .

Load Factors

15. In the Wasserfall computations the basic aerodynamic data result in a relatively large distance from the center of pressure to the center of gravity after passing through the speed of sound. For this reason, the angle of incidence which can be attained at maximum deflection of the control surfaces is not especially large, and the same is true also for the load factor. Trajectory computations at Gorodomya gave a load factor of $\eta \approx 2$. In such trajectories, no evasive action can be assumed on the part of the target. (The maximum value of η was not definitely known.)
16. In the requirements for the R-113, it was stated that the rocket must be able to attack targets which made defensive maneuvers up to $\eta = 2.5$. Therefore, the R-113 had to be able to reach a load factor of $\eta = 5$. This requirement was fulfilled for the lower and medium altitudes of the combat zone. However, at the upper limit of the combat zone where the impact pressure was only between 1 and 2 tons/m^2 , the lift of at least 7.5 tons, which is necessary for the load factor $\eta = 5$, cannot be attained.

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		Wasserfall		R-113
1. <u>Dimensions</u>				
Length	1	(m)	7.5-8.0	9
2. <u>Weight</u>				
Take-off weight	G_0	(kg)	3800	3800
Weight at burn-out	G_{Br}	(kg)	1730	1500
Fuel Weight	G_T	(kg)	2070	2300
Mass ratio	M_{Br}	(1)	0.455	0.39
3. <u>Payload</u>	G_N	(kg)	500(?)	500
4. <u>Thrust</u>				
Thrust on ground	S_0	(kg)	8000	9500-8600
Fuel Consumption	$ \dot{G} $	(kg/sec)	45	51.5-47
Exhaust velocity	C	(m/sec)	1750	1800
Burning time	t_{Br}	(sec)	46	see text
Special thrust acceleration	σ	(1)	2.1	2.50-2.27
5. <u>Vertical ascent</u>				
Burn-out velocity	V_{Br}	(m/sec)	800	1000
Burn-out altitude	h_{Br}	(km)	14.3	>30
Maximum impact-pressure	g_{max}	(ton/m ²)	8	10
6. <u>Sloping trajectory (up to $\theta = 30^\circ$)</u>				
Burn-out velocity	V_{Br}	(m/sec)	800	1100
Burn-out altitude	h_{Br}	(km)	8.2	20-25
Maximum impact-pressure	g_{max}	(ton/m ²)	17	17-20

Table 1

Comparative data of Wasserfall and R-113

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			Vertical Ascent		Sloping Trajectory			
μ	t	v	h	g	γ	h	x	g
(1)	(sec)	(m/sec)	(km)	(ton/m ²)	(°)	(km)	(km)	(ton/m ²)
1.00	0.0	0	0.00	0.00	90	0.00	0.00	0.00
0.90	8.4	97	0.41	0.57	75	0.40	0.05	0.57
0.80	16.9	193	1.63	1.99	50	1.47	0.64	2.02
0.70	25.3	301	3.69	3.91	30	2.70	2.27	4.33
0.60	33.8	453	6.83	6.30	30	4.27	4.99	8.34
0.50	42.2	676	11.46	7.91	30	6.63	9.08	14.34
0.455	46.0	800	14.30	7.08	30	8.20	11.80	16.76

Table 2Values for the Powered Trajectory of the Wasserfall

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Vertical Ascent					Sloping Trajectory				
μ	t	v	h	q	γ	v	h	x	q
(1)	(sec)	(m/sec)	(km)	(ton/m ²)	(°)	(m/sec)	(km)	(km)	(ton/m ²)
1,00	0,0	0	0,00	0,00	90	0	0,00	0,00	0,00
0,90	7,3	117	0,42	0,82	75	116	0,41	0,05	0,81
0,80	14,7	253	1,77	3,36	50	256	1,58	0,71	3,51
0,70	22,0	384	4,13	6,14	30	406	3,03	2,62	7,62
0,60	29,4	562	7,55	8,91	30	603	4,86	5,78	13,86
0,50	36,7	806	12,53	9,46	30	876	7,48	10,32	21,82
0,40	44,0	1128	19,57	6,12	30	1223	11,30	16,94	26,55
0,39	44,7	1166	20,39	5,81	30	1262	11,75	17,72	26,28
	48,7	1126	24,97	2,75	30	1246	14,26	22,07	17,35
	52,7	1086	29,40	1,33	30	1230	16,73	26,36	11,35
	56,7				30	1214	19,18	30,59	7,54
	60,7				30	1198	21,59	34,77	5,09
	64,7				30	1182	23,97	38,89	3,41
	68,7				30	1166	26,32	42,96	2,30
	72,7				30	1150	28,63	46,97	1,57

Table 3

Trajectory Values for the R-113 When Flown Without Thrust Decrease

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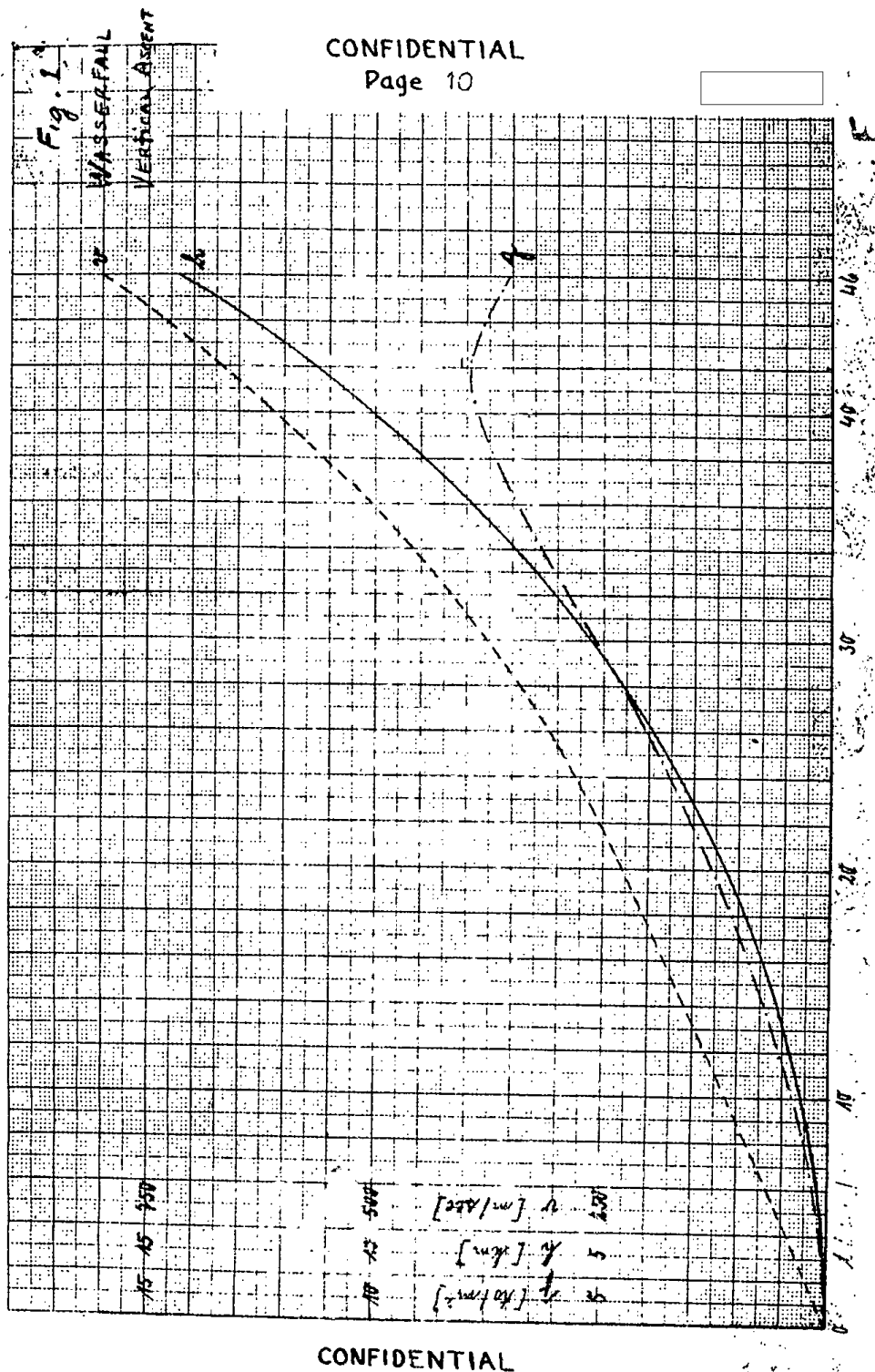
<i>h</i> (km)	<i>V</i> (m/sec)
3	464
4	489
5	516
6	545
7	577
8	611
9	648
10	689
11	734

<i>h</i> (km)	<i>V</i> (m/sec)
12	794
13	859
14	930
15	1006
16	1089
17	1179
18	1275
19	1380
20	1493

Table 4

Maximum Permissible Velocity Dependent on Height, If the Impact Pressure of 10 ton/m² Is Not Exceeded.

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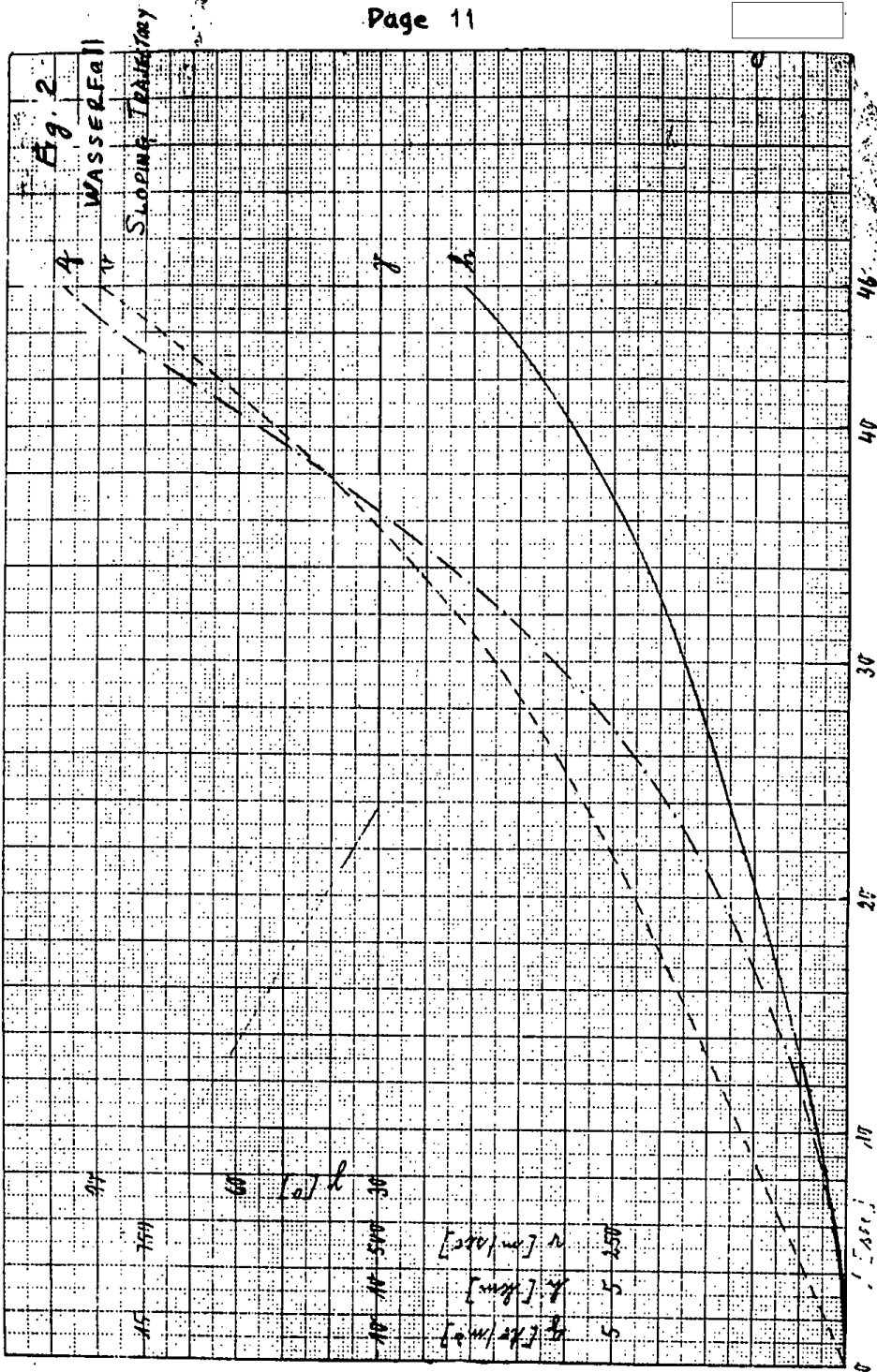


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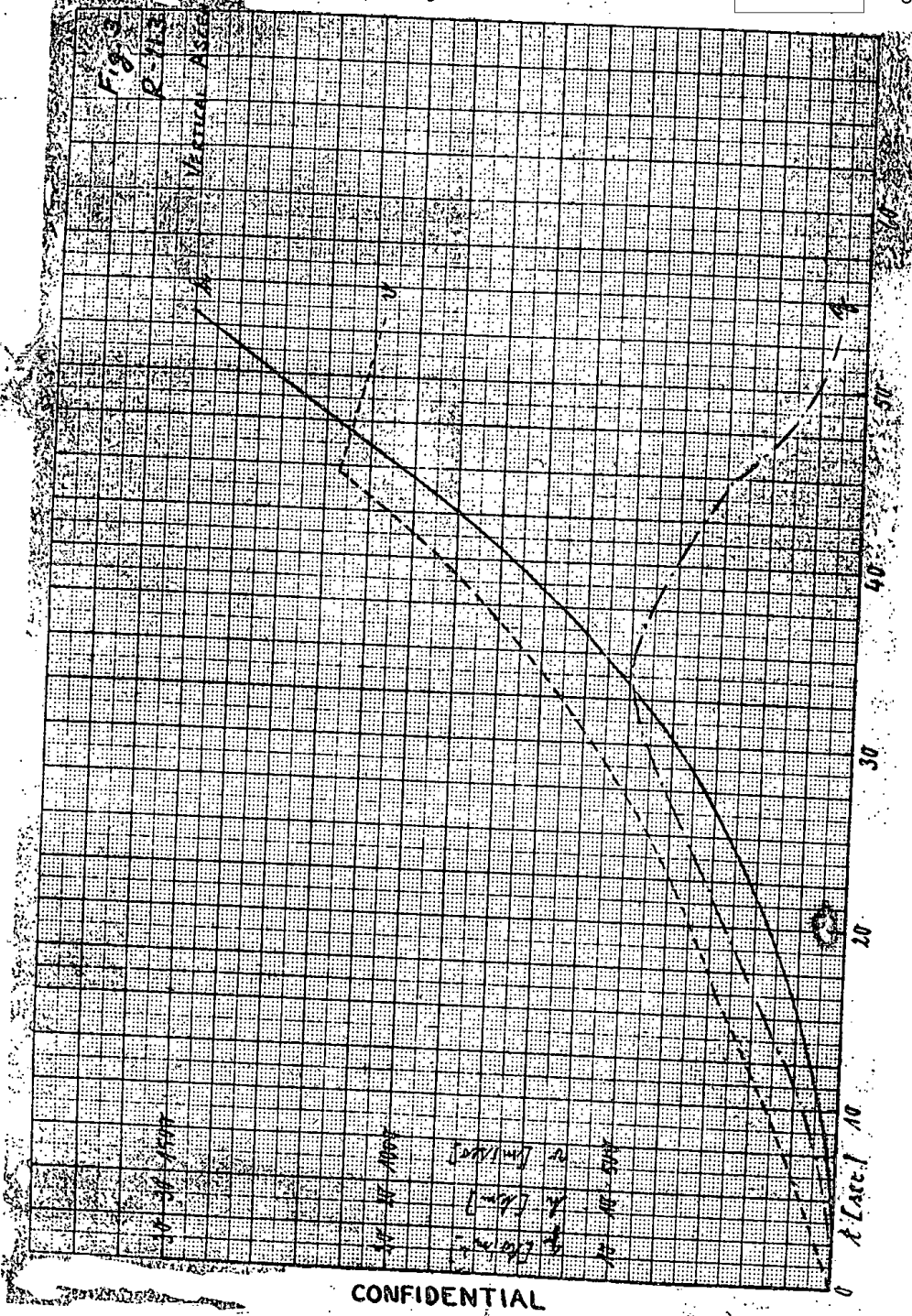
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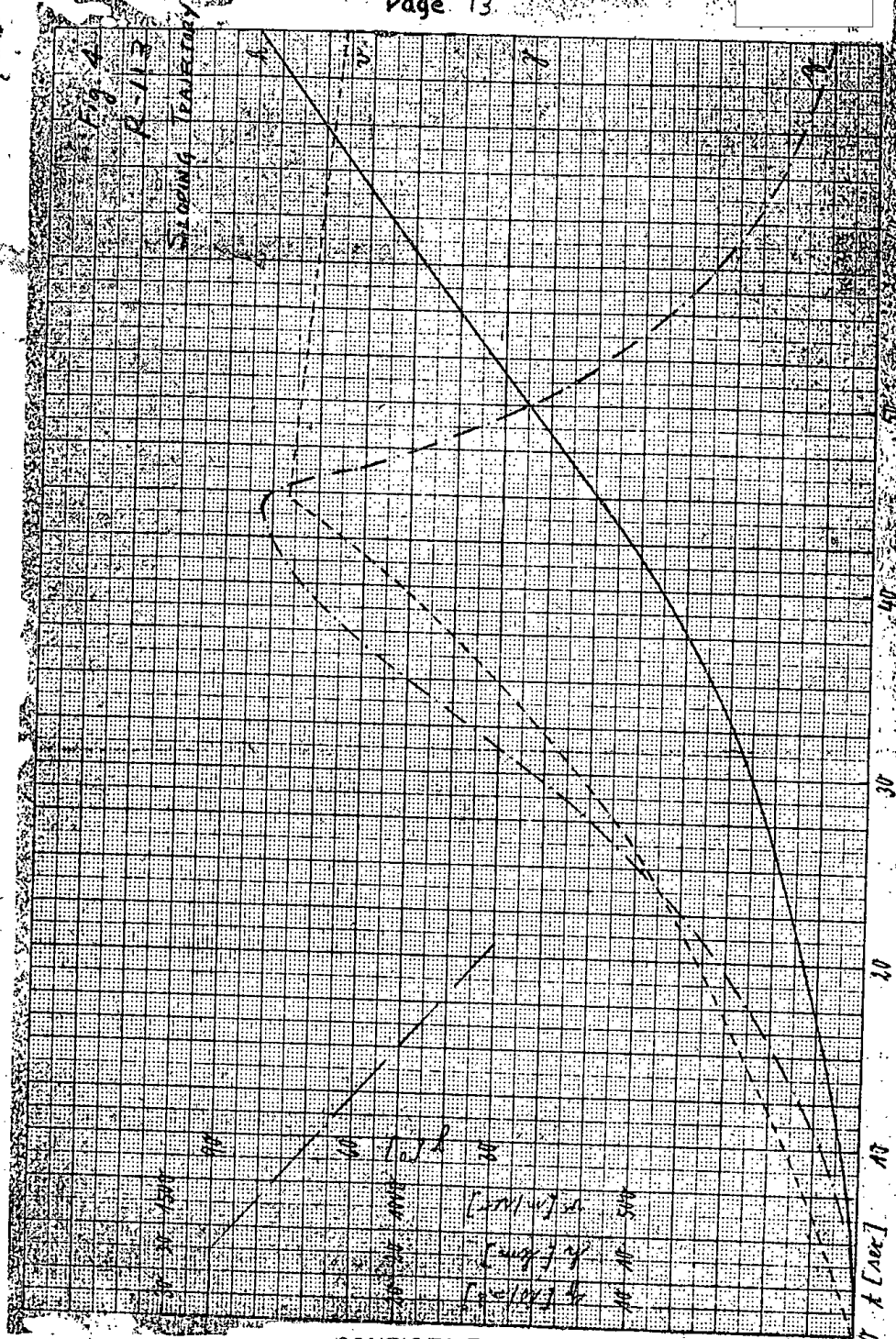
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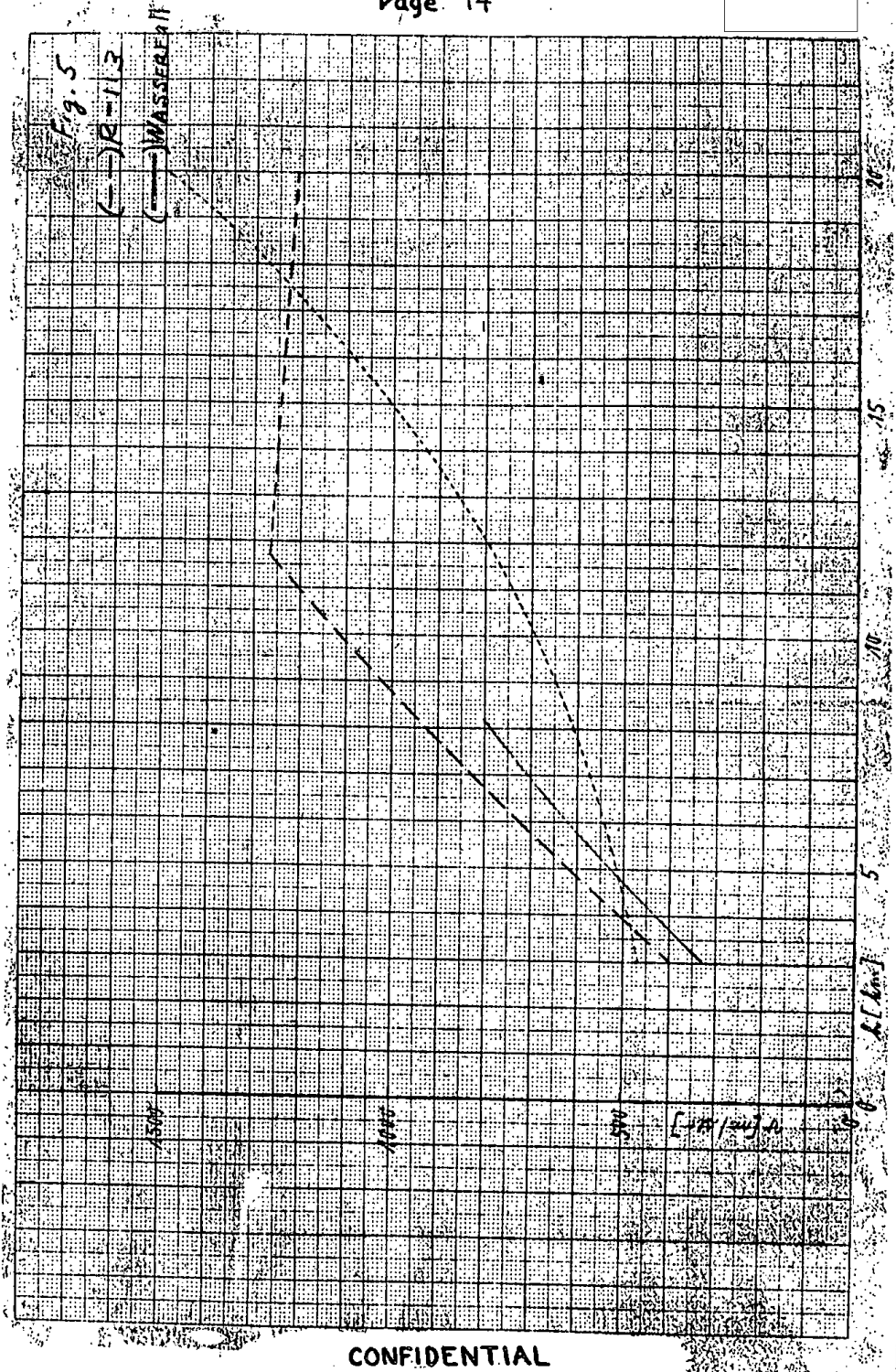


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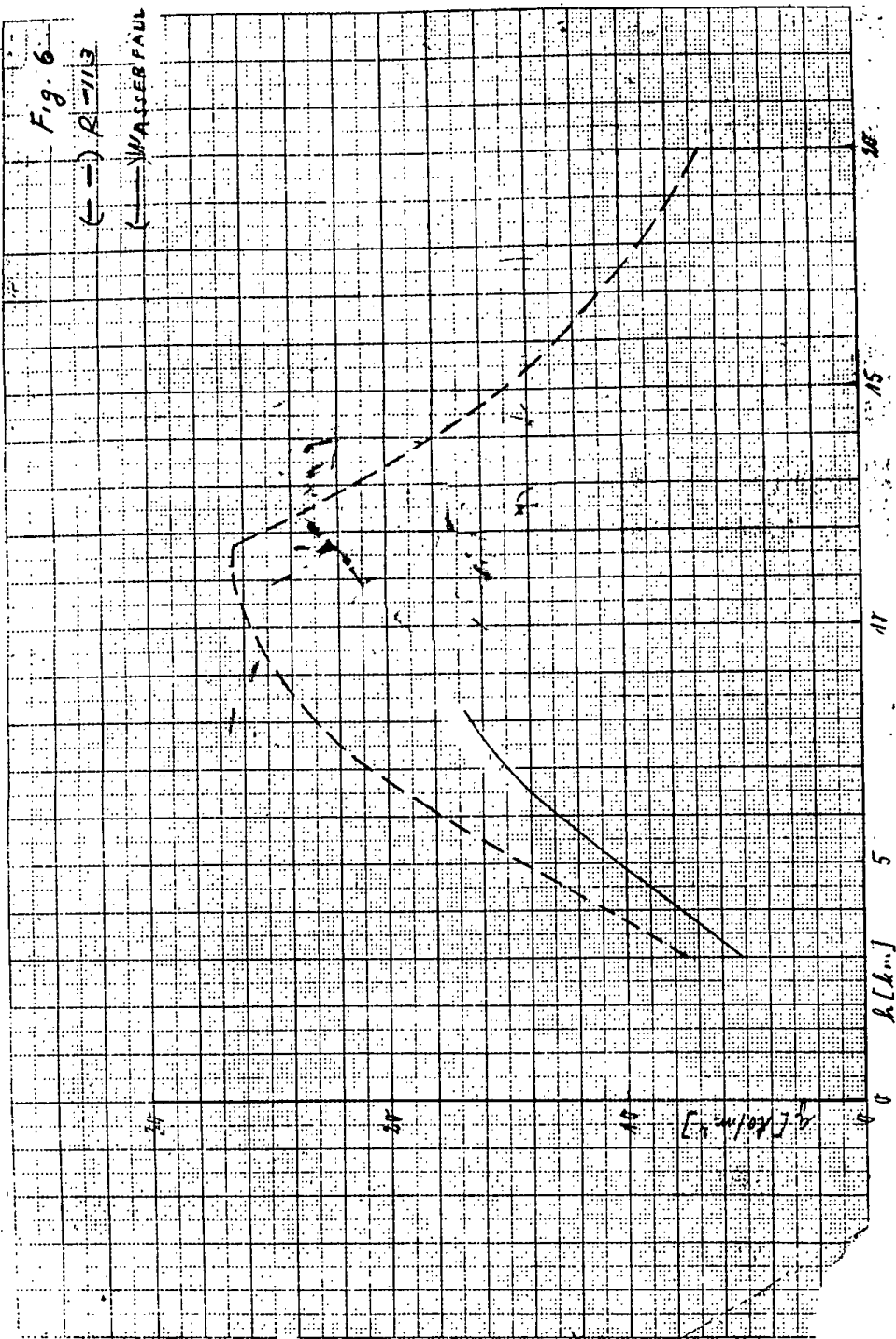
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